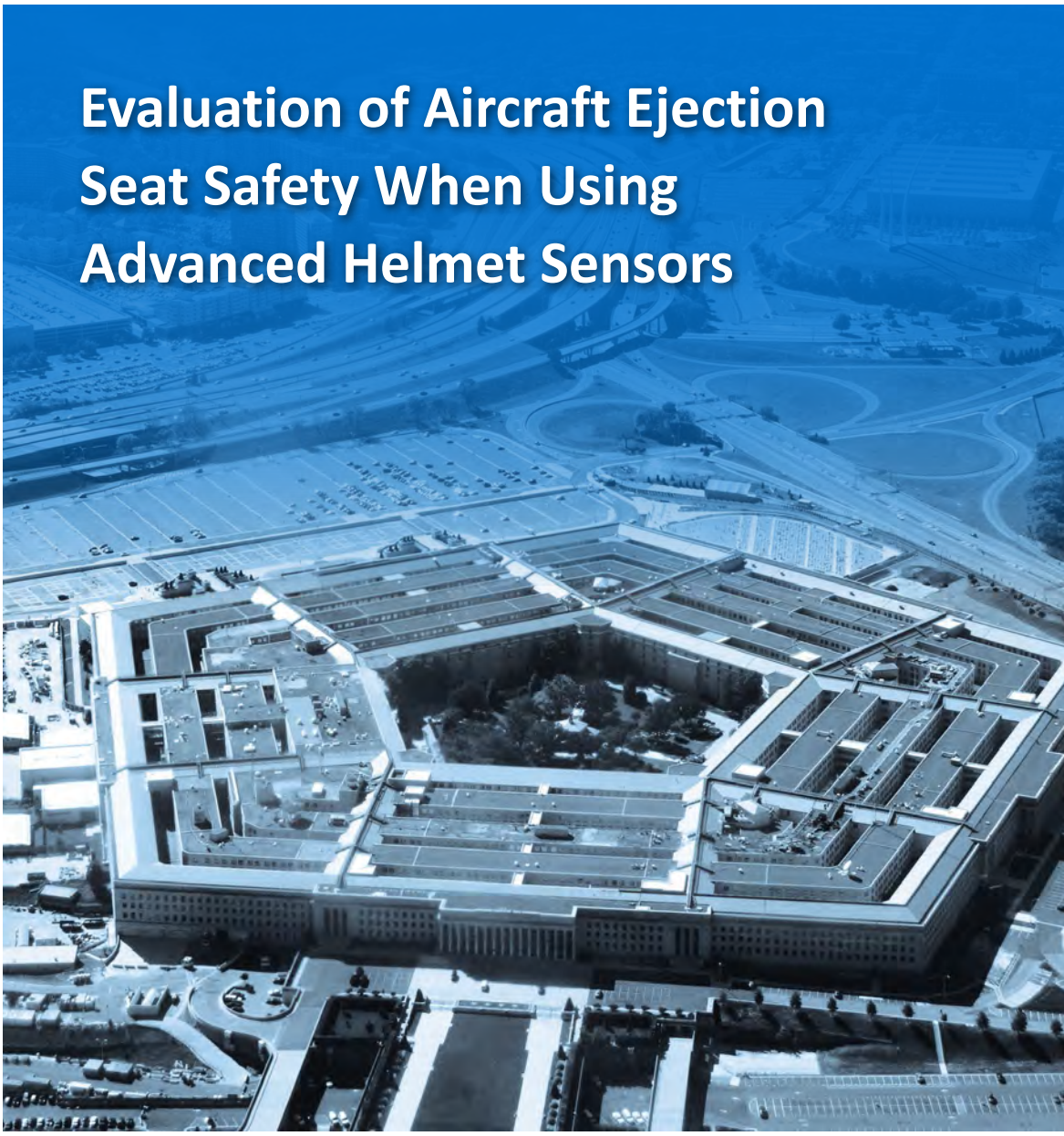
Report No. DODIG-2015-090

INSPECTOR GENERAL

U.S. Department of Defense

MARCH 9, 2015

Evaluation of Aircraft Ejection Seat Safety When Using Advanced Helmet Sensors



INTEGRITY ★ EFFICIENCY ★ ACCOUNTABILITY ★ EXCELLENCE

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
09 MAR 2015		**00-00-2015 to 00-00-2015**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Evaluation of Aircraft Ejection Seat Safety When Using Advanced Helmet Sensors	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **U.S. Department of Defense Inspector General,4800 Mark Center Drive,Alexandria,VA,22350-1500**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**44**	

INTEGRITY ★ EFFICIENCY ★ ACCOUNTABILITY ★ EXCELLENCE

Mission

Our mission is to provide independent, relevant, and timely oversight of the Department of Defense that supports the warfighter; promotes accountability, integrity, and efficiency; advises the Secretary of Defense and Congress; and informs the public.

Vision

Our vision is to be a model oversight organization in the Federal Government by leading change, speaking truth, and promoting excellence—a diverse organization, working together as one professional team, recognized as leaders in our field.

For more information about whistleblower protection, please see the inside back cover.

Results in Brief

Evaluation of Aircraft Ejection Seat Safety When Using Advanced Helmet Sensors

March 9, 2015

Objective

We are issuing this report in response to a request from Congress through the National Defense Authorization Act (NDAA) for Fiscal Year 2015. We determined whether DoD aircraft ejection seats meet aircrew survivability and equipment airworthiness requirements for pilots and aircrew wearing helmet-mounted displays (HMDs), night vision goggles (NVGs), or both during flight operations.

Findings

Our evaluation found:

A. DoD ejection seat equipped aircraft with aircrew wearing HMDs and/or NVGs meet airworthiness criteria in accordance with DoD Military Handbook 516B, "Airworthiness Certification Criteria," (MIL-HDBK-516B) and have been certified safe-to-fly by the appropriate Navy and Air Force acceptance authorities. However, both Services noted that there is an increased risk of neck injury during high-speed ejections with HMDs and/or NVGs above 450 Knots Equivalent Air Speed (KEAS), and an increased potential of neck injuries for low-weight pilots. To mitigate these risks, both Services placed warnings, notes, cautions, and restrictions in the flight manuals.

B. In addition, the Joint Service Specification Guide (JSSG), "Crew Systems, Emergency Egress Handbook," October 1998, has not been revised or updated as required by DoD Manual 4120.24, "Defense Standardization Program (DSP), Policies and Procedures."

Findings (cont'd)

Furthermore, our evaluation concluded that the overall risk of ejection is remote. Also, the addition of HMDs and/or NVGs does not significantly increase the risk of major injury during ejection if the aircrew is following proper ejection procedures described in the Naval Air Training and Operating Procedures (NATOPS) or the Air Force flight manuals. Regardless of the helmet system being worn, if aircrew do not properly wear helmets at all times and follow proper ejection procedures, they are susceptible to an increased risk of head and neck injuries in the event of an ejection.

Recommendations

Although the ejection systems with NVGs/HMDs have been deemed airworthy by their respective Services, we recommend that the Navy and Air Force:

A.1. Continue to evaluate technology that would improve the overall safety of the pilot during ejections.

A.2. Ensure consistent documentation of aircraft ejection data to increase the data available for ejections with HMD and/or NVGs thus improving the safety risk analysis.

A.3. Ensure increased emphasis during training, annual checkrides, and continually stressed awareness that aircrew are following proper ejection procedures as identified in the NATOPS and the Air Force flight manuals.

B. We recommend that the Navy and Air Force review and update the JSSG to reflect changes in policy and technology that have occurred in the last 16 years.

Visit us at www.dodig.mil

Results in Brief

Evaluation of Aircraft Ejection Seat Safety When Using Advanced Helmet Sensors

Management Comments and Our Response

The Deputy Assistant Secretary of the Navy, Air Programs, agreed with three recommendations and partially agreed with one recommendation. The Deputy's comments did not address how the recommendations would be implemented. We request that the Deputy Assistant Secretary of the Navy, Air Programs, provide additional comments in response to this report by March 25, 2015.

The Air Force Life Cycle Management Center agreed with all the recommendations, and its implementation plan is acceptable. We request a copy of the JSSG, "Crew Systems, and Emergency Egress Handbook," once the update is complete. See the Recommendations Table on the following page.

Recommendations Table

Management	Recommendations Requiring Comment	No Additional Comments Required
Deputy Assistant Secretary of the Navy, Air Programs	A.1, A.2, A.3, and B	
Air Force Life Cycle Management Center		A.1, A.2, A.3, and B

Please provide comments by March 25, 2015.

INSPECTOR GENERAL
DEPARTMENT OF DEFENSE
4800 MARK CENTER DRIVE
ALEXANDRIA, VIRGINIA 22350-1500

March 9, 2015

MEMORANDUM FOR DEPUTY ASSISTANT SECRETARY OF THE NAVY, AIR PROGRAMS
NAVAL AIR SYSTEMS COMMAND
NAVAL AIR SYSTEMS COMMAND/AIR CREW SYSTEMS
AIR FORCE MATERIEL COMMAND
AIR FORCE LIFE CYCLE MANAGEMENT CENTER

SUBJECT: Evaluation of Aircraft Ejection Seat Safety When Using Advanced Helmet Sensors (Report No. DODIG-2015-090)

We are providing this report for review and comment. The DoD Office of the Inspector General conducted this evaluation in response to a request from Congress through the National Defense Authorization Act (NDAA) for Fiscal Year 2015. Our objective was to evaluate whether DoD ejection seats meet aircrew survivability and equipment airworthiness requirements for pilots and aircrew wearing helmet-mounted displays (HMDs), night vision goggles (NVGs), or both during ejection. We conducted this evaluation in accordance with the Council of Inspectors General on Integrity and Efficiency Quality Standards for Inspection and Evaluation.

We determined through the course of this evaluation that the overall risk of ejection is remote and the addition of HMDs and/or NVGs does not significantly increase the risk of major injury if the aircrew is following proper ejection procedures described in the flight manual. Additionally, we found that the Joint Service Specification Guide (JSSG), "Crew Systems, Emergency Egress Handbook," dated October 1998 has not been updated in accordance with DoD policy.

We considered management comments on a draft of this report when preparing the final report. DoD Instruction 7650.03 requires that recommendations be resolved promptly. As a result of management comments, we revised Recommendation A.3 to allow for the Services to determine the best place for increased emphasis and awareness on proper ejection procedure. Comments from the Air Force Life Cycle Management Center, Human Systems Division, were responsive, and we do not require additional comments. Comments from the Deputy Assistant Secretary of the Navy, Air Programs, did not address the specifics of Recommendations A.1, A.2, A.3, and B. Therefore, we request further comments by March 25, 2015.

Please provide comments that conform to the requirements of DoD Instruction 7650.03. If possible, please send a PDF file containing your comments to heather.moore@dodig.mil. Copies of your comments must have the actual signature of the authorizing official for your organization. We cannot accept the /Signed/ symbol in place of the actual signature. If you arrange to send classified comments electronically, you must send them over the SECRET Internet Protocol Router Network (SIPRNET).

We appreciate the courtesies extended to the staff. Please direct questions to Captain Christopher Failla, USN, at Christopher.Failla@DODIG.mil or (703) 604-8915 (DSN 664-8952).

Randolph R. Stone
Deputy Inspector General
Policy and Oversight

cc:
Secretary of the Navy
Secretary of the Air Force
Under Secretary of Defense for Acquisition, Technology, and Logistics

Contents

Introduction

Objective

We determined whether DoD aircraft ejection seats meet aircrew survivability and equipment airworthiness requirements for pilots and aircrew wearing helmet-mounted displays (HMDs), night vision goggles (NVGs), or both during flight operations.

Background

This report is in response to a request from Congress through the National Defense Authorization Act (NDAA) for Fiscal Year 2015. Congress requested the DoD Office of Inspector General (OIG) provide a report that outlines which DoD ejection seat equipped aircraft meet the aircrew survivability and equipment airworthiness requirements for pilots and aircrew wearing HMDs and NVGs. Congress' concern is that the incorporation of modern HMDs, such as the Joint Helmet-Mounted Cueing System (JHMCS), increases the risk to pilots during high-speed ejections. Specifically, they are concerned that the aerodynamic forces can lift the helmet off the pilot, causing high neck tension loads during high-speed ejections. They are also concerned that ejection criteria in the DoD Military Handbook 516B, "Airworthiness Certification Criteria," February 2008, (MIL-HDBK-516B) for Airworthiness Certification Criteria are not being met; specifically they cited that the 5-percent risk of major injury resulting from an aircraft ejection event was not being met for legacy fighters or fifth generation tactical aircraft.

Airworthiness Process

The airworthiness certification process is employed by the Navy and Air Force to evaluate aircraft airworthiness prior to flight. The certification verifies that a specific air vehicle system can be safely maintained and operated within its described flight envelope and can safely attain, sustain, and terminate a flight in accordance with approved usage limits (such as, range, speed, weight, altitude, and safety). Airworthiness certification is required for any fixed-wing and unmanned vehicle that is new or has had any modifications to its configuration and/or performance envelope. The airworthiness certification requirements are listed in multiple DoD guides, handbooks, military standards, instructions, and regulations. The two main criteria are MIL-HDBK-516B and the Joint Service Specification Guides (JSSGs)-2010, October 1998. Both documents are for guidance only and cannot be cited as a contractor requirement.

MIL-HDBK-516B establishes the airworthiness certification criteria to be used in determining airworthiness of all manned and unmanned, and fixed- and rotary-wing air vehicle systems. It is a foundational document that is used by the system program manager, chief/lead systems engineer, and contractors to

define their air system's airworthiness certification basis. The criteria can be tailored and applied at any point throughout the life of an air vehicle system when an airworthiness determination is necessary, and whenever there is a change to the functional or product baseline. The Handbook has several sections for each function of the aircraft. Each section is matched with a corresponding JSSG. Specifically, MIL-HDBK-516B Section 9, "Crew Systems," outlines the elements required for verification of escape and egress systems, and life support systems. The MIL-HDBK-516B provides a generalized list of typical data required for airworthiness approval from the Services, such as validation, testing, and analyses reports used in the certification of aircraft systems. In all instances, complete and accurate documentation of both applicability and system-specific measurable criteria values are critical to ensuring consistent, timely, and accurate airworthiness assessments.

MIL-HDBK-516B provides a listing of required documents for verification of various aircraft systems, and the JSSG-2010-11, "Crew Systems, Emergency Egress Handbook," is a template and establishes a common framework to be used by Government-industry program teams for developing program-unique requirements documents for air systems. By design, the JSSG is written as a template for "requirements" and "verification criteria," with blanks that need to be completed by the program office in order to make the requirements meaningful. The JSSG captures the essential performance objectives needed for aviation systems that are often buried within the "how-to" detail specifications and military standards. To help program teams understand the basis for each requirement, the JSSG defines the rationale for requirements and guidance on how to apply or tailor them. In this way, program teams can more easily adapt or modify the JSSG sample requirement statements to meet the specific needs of an individual program.

MIL-HDBK-516B states, "Verify that the escape systems shall be safe for human use and compatible with the aircraft." It then cites the JSSG-2010-11, which includes detailed requirements, such as egress system acceleration limits. MIL-HDBK-516B also indicates that where the life support system interfaces with other air vehicle subsystems, it should not degrade the normal or failure modes of operation of those subsystems such as the escape system. Additionally, the system should satisfy the physiological requirements of the occupants during mission, escape, and survival. Although the NDAA cites a 5-percent requirement, MIL-HDBK-516B dated February 2008 does not cite a 5-percent probability of human incapacitating injury. However, the "ASC/EN Air worthiness Certification Criteria Expanded Version of Mil-HDBK-516B" dated September 2005, which is specific to the Air Force, lists a 5-percent requirement, but MIL-HDBK-516B dated February 2008 supersedes it. Both the Navy and Air Force use the 5-percent as a best practice. Likewise, the JSSG-2010-11, which is referenced by MIL-HDBK-516B, states that the escape system shall provide a means that allows the crew to abandon the aircraft, within the

systems' defined performance envelope, with no injuries that will compromise their survival. It does not cite the 5-percent probability of major injury as a requirement. However, the JSSG-2010-11 states that analysis shall be provided to show that all reasonable precautions have been taken to reduce the potential for injury during the ejection process.

Both the Air Force and Navy use these handbooks to develop and establish their own policies and procedures for granting airworthiness certifications. The following discusses the current Air Force and Navy Airworthiness policies.

Air Force

The Air Force Policy Directive (AFPD) 62-6, "USAF Airworthiness," and Air Force Instruction (AFI) 62-601, "USAF Airworthiness," both dated June 2010, establish the formal airworthiness assessments process to ensure that Air Force operated aircraft are airworthy over their entire life cycle and maintain high levels of safety. The process assigns the Air Force Life Cycle Management Center, Engineering and Technical Management/Services Directorate (AFLCMC/EN-EZ) as the technical airworthiness authority and serves as an independent body overseeing airworthiness assessments. AFLCMC/EN-EZ issues the Military Type Certificate that provides the evidence that the aircraft system type design is in full compliance with its approved certification basis. Each aircraft platform Program Office is responsible for granting the Military Certificate of Airworthiness for each individual aircraft showing it in compliance with the Military Type Certificate. AFLCMC/EN-EZ as the technical authority also provides technical guidance and recommendations to the aircraft Program Office to determine if modifications to individual aircraft affect Military Certificate of Airworthiness and/or the Military Type Certificate.

The airworthiness certification takes into account the complete airframe and any items worn, installed, or operated on or any modifications to the aircraft. The Human System Division (HSD) within AFLCMC performs safe-to-fly assessments specific to items worn, by the aircrew during flight. HSD performs integration testing on new items, evaluates system flight safety, and then provides safe-to-fly recommendations to the aircraft program offices. In order to be considered safe-to-fly, the item should not cause any unacceptable hazards to the user, crew, or aircraft, not interfere with proper use of other mission equipment, and not modify or change a configuration/system that is covered by a technical order. Although, HSD does not grant airworthiness certifications, they provide a safe-to-fly recommendation that helps support the platform airworthiness certification process.

The aircraft program office review all the risks associated with their specific aircraft, the safe-to-fly recommendations, and then make a determination to accept any risks and provide Military Certificate of Airworthiness.

Navy

Naval Air Systems Command (NAVAIR) Instruction 13034.1D, "Flight Clearance Policy for Air Vehicles and Aircraft Systems," dated March 2010, establishes policy, responsibilities, and procedures for executing airworthiness reviews resulting in NAVAIR flight clearances for all Navy air vehicles and aircraft systems. Flight clearance is the formal evidence that an engineering assessment has been successfully completed by the cognizant technical areas, which indicates the aircraft system can be operated with an acceptable level of technical risk. The NAVAIR Flight Clearance Office (AIR 4.0P) maintains the overall responsibility for the Navy's flight clearances and is the ultimate release authority.

All new or modified aircrafts, avionics, software, man-mounted equipment, and modifications must go through the flight clearance and airworthiness process. The flight clearance process involves an independent engineering assessment of airworthiness, safety of flight, and risk. The intent of assessing safety of flight is to show that the level of risk (hazard to the system, personnel, property, equipment, and environment) has been appropriately identified by the Technical Area Experts, reviewed, and accepted by the appropriate authority. Every system has to independently meet airworthiness criteria. For example, the headgear and escape system each go through the verification and certification process individually at a component level and then again at the system level to achieve full ejection system integrated performance for the overall air system configuration. This process builds up to achieve the overall aircraft system airworthiness certification.

Helmet-Mounted Devices

Both the Navy and Air Force use the standard fixed-wing aircrew HGU-55/P helmet that is shown in Figure 1. It weighs about 2.67 pounds (lbs.) with the oxygen mask and visor and designed to withstand windblasts of up to 450 Knots Equivalent Air Speed (KEAS). Adding the night vision systems and the helmet-mounted cueing systems, which are affixed to the top/front of the HGU-55/P, can increase the overall helmet weight to almost 5 lbs., depending upon the type of NVG or HMD.

Figure 1. HGU-55/P Helmet
Source: Air Force

Shown in Figure 2 are four NVG and HMD systems: AN/AVS-9 Night Vision Goggle (NVG), AN/AVS-10 Panoramic NVG (PNVG) (Air Force only), JHMCS, and the Helmet-Mounted Integrated Targeting (HMIT) system (Air Force only). Helmets with NVG or PNVG weigh 4.31 lbs. and 4.88 lbs., respectively. Both the NVG and PNVG are to be removed before ejection, as stipulated in the Naval Air Training

and Operating Procedures (NATOPS) and Air Force flight manuals. If the aircrew do not remove and stow the NVG or PNVGs before ejection, the ejection forces will dislodge them from the helmet mount and possibly cause injury.

Two helmet systems support weapon cueing: JHMCS for the Navy and Air Force, and HMIT for the Air Force only. JHMCS with helmet weighs 4.33 lbs. for the day version and 4.81 lbs. for the JHMCS helmet with NVGs. The HMIT with helmet weighs 4.77 lbs. for the day version and 3.95 lbs. for the night version without NVG and 5.05 lbs. with NVGs. Both systems are certified to the same windblast level as the base helmet. However, HMDs are not removed and stowed because they are designed to provide facial protection during ejection.

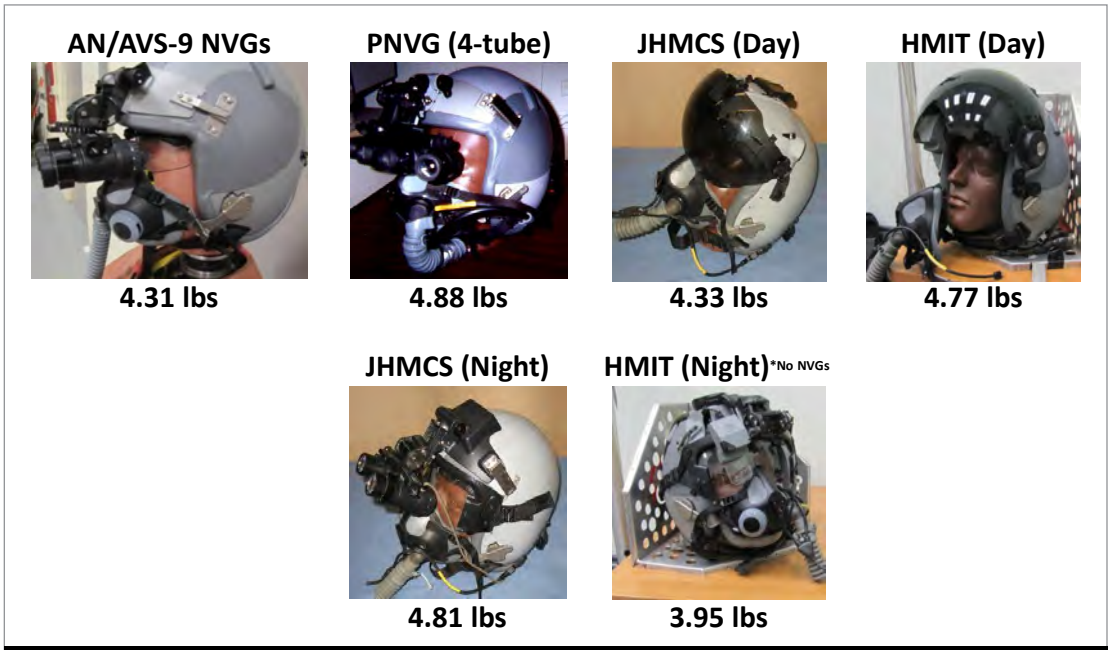


Figure 2. Helmet-Mounted Devices
Source: Air Force

Ejection Seats

Advanced Concept Ejection Seat II (ACES II)

The Air Force has 5,208 ejection seats in its inventory supporting 12 aircraft types (Table 1). Of those seats, approximately 2,813 are the Advanced Concept Ejection Seat II (ACES II), which is currently the primary ejection seat in operational use by the Air Force. Originally produced and first introduced by McDonnell Douglas in 1978, ACES II is now being built by United Technologies Corporation (UTC), Aerospace System (UTAS), in Colorado Springs, Colorado, and supports six aircraft platforms.

The ACES II is designed to structurally support windblast forces at a maximum velocity of 600 KEAS and an altitude of 60,000 ft. It provides "safe open-air" ejections for aircrew between 140 to 211 lbs. nude body weight and between 0 to 450 KEAS. Above 500 KEAS, limb flail becomes an issue and may lead to injuries. The Air Force notes in their flight manuals that aircrew weighing less than 140 lbs. nude body weight have a higher risk of injury above 350 KEAS due to drogue chute deployment. The ACES II seat is used in all aircraft variants that support HMDs and/or NVGs (Table 1). We focused specifically on the ACES II seat because that is where the majority of HMDs and/or NVGs are used. We did not look at other ejection seat equipped aircraft using other seat types because they do not use HMDs and/or NVGs or do not support speeds above 350 KEAS during their flight operation; thus are outside the scope of this evaluation.

Table 1. Air Force Aircraft with Ejection Seat Type Supporting NVGs/HMDs

Aircraft	Seat Type	# of Seats	Helmet-Mounted Devices			
			AVS-9 (NVG)	AVS-10 (PNVG)	JHMCS	HMIT
A-10	ACES II	321	X	X		X
B-1	ACES II	248	X			
B-2	ACES II	40				
F-15	ACES II	719	X	X	X	
F-16	ACES II	1299	X	X	X	X
F-22	ACES II	186	X			
B-52	Weber	456	X			
U-2	Lockheed	27				
TU-2	Lockheed	10				
T-38A/B	Northrop	118				
T-38C	MK-US16T	892				
T-6	MK-US16LA	892				

Source: Air Force

Navy Aircrew Common Ejection Seat (NACES)

The Navy has 2,986 ejection seats, with 12 seat variants that support 9 aircraft types. Of those seats, approximately 1,958 are Navy Aircrew Common Ejection Seats (NACES), also known as SJU-17 (Table 2). The NACES SJU-17 is the common ejection seat designed for incorporation into the F-18, EA-18G and T-45 aircraft. It is built by Martin Baker and was introduced in 1991 in the F-18C/D aircraft variant, with all other F-18 variants being upgraded to the NACES seat. The Navy is upgrading to this seat because it is the only seat that can support the JHMCS,

with other seat variants able to support only NVGs. The NACES was certified up to 600 KEAS and up to 60,000 feet. It provides "safe open-air" ejections for aircrew between 136 to 213 lbs. nude body weight and 0 to 450 KEAS. However, within the NATOPS, the Navy notes the safe ejection envelope is reduced to 0 to 350 KEAS when the aircrew is wearing the JHMCS.

Table 2. Navy Aircraft Supporting HMDs and/or NVGs

Aircraft	Seat Type	# of Seats	Helmet-Mounted Devices	
			AVS-9 (NVG)	JHMCS
T/AV-8B	SJU-4, SJU-13, SJU-14	147	X	
EA-6B	GRUEA-7	152	X	
F-18 A/B/C/D	SJU-5, SJU-6	142	X	
F-18 A/B/C/D/E/F	SJU-17	1354	X	X
EA-18G	SJU-17	206	X	X
F-5	Northop Improved Rocket	47		
S-3	ESCAPAC IE-1	12		
T-6	MK-US16LB	510		
T-38C	MK-US16T	20		
T-45	SJU-17	398		

Source: Navy

ACES 5

The ACES 5 ejection is seat currently under development by UTAS. UTAS completed testing in February 2010 and provided results to the Air Force for verification. The Air Force has not completed qualification testing on the seat. Because the seat is not completely qualified, it was not included in this evaluation. The ACES 5 is designed to provide safe ejection for aircrew weighting between 103 to 245 lbs. nude body weight from 0 to 600 KEAS. The seat has a passive head and neck protection, arm and leg restraints, and a new parachute. The seat is also compatible with current HMDs and/or NVGs.

MK16 – US16E Ejection Seat

The MK16 developed by Martin Baker was selected by Lockheed Martin as the ejection seat for the System Development and Demonstration phase of the F-35 program. The seat is designed to provide safe ejection for aircrew weighing between 103 to 245 lbs. nude body weight from 0 to 600 KEAS. We did not analyze the F-35 seat because a limited number have been delivered, there is limited ejection data, and the F-35 program is still conducting qualification testing of the overall aircraft system.

Ejection Sequence

Ejection is a multi-phase event that exerts several different forces on the pilot in approximately two seconds (Figure 3). We used an F-16 ACES II mode 2 ejection at 600 KEAS to describe the ejection sequence. A typical ejection sequence lasts 2-3 seconds from initiation to parachute inflation. When the pilot first pulls the ejection handles the canopy blows off, and the pilot is subjected to approximately 4,000 lbs. of upward thrust from the seat catapult, as shown in Figure 3 Phase A and B. This upward force causes a downward reaction on the pilot's body and can force the head down. The upward force is usually enough to dislodge NVGs; however, the pilot should have removed the NVGs before ejection in accordance with proper procedure.

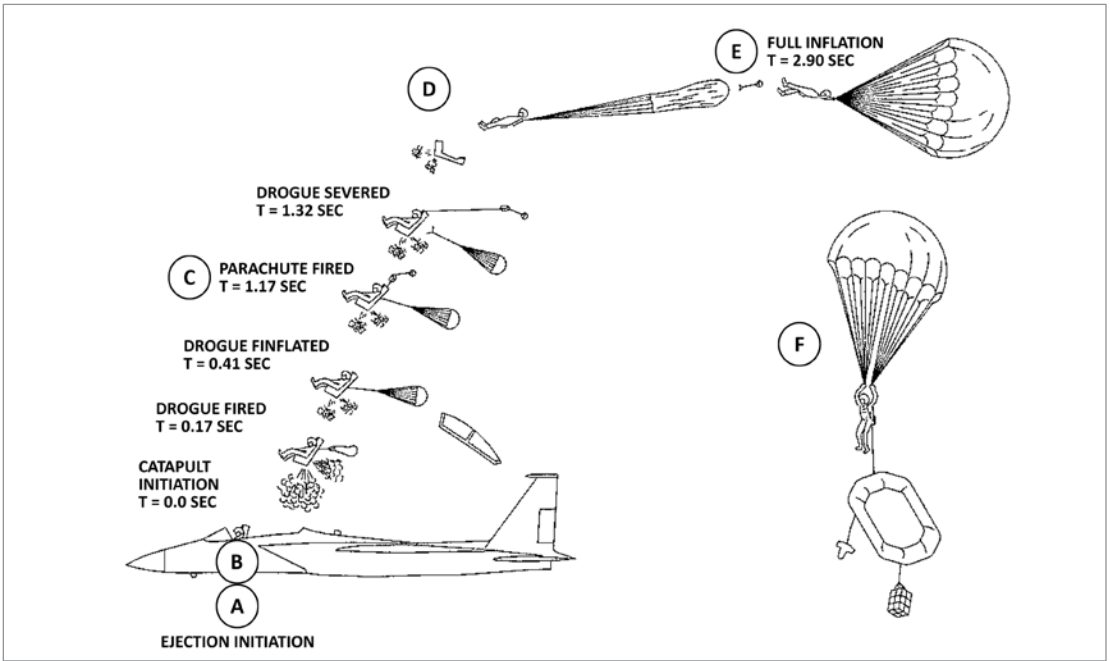


Figure 3. Ejection Phases
Source: Air Force

Once the pilot clears the aircraft, she/he will experience windblast forces of up to 1,200 lbs. per square foot at 600 KEAS, as shown in Figure 3 Phase B to C. This pushes the pilot's head back against the seat; limbs are also pushed towards the back of the ejection seat by the wind. At this stage if the helmet is not properly positioned and the chin straps are not tight enough, the windblast may cause the helmet to pull up on the head and neck.

About 0.4 seconds into the ejection sequence, a rocket fires to stabilize the seat followed immediately by the drogue parachute being deployed, which exerts approximately 7,600 lbs. of backward force on the pilot, as shown in Figure 3 Phase B to C. This slows the pilot's freefall and further stabilizes the seat.

At about 1.8 seconds the main parachute then deploys exerting approximately 3,000 lbs. of force on the pilot's body and the ejection seat falls away, as shown in Figure 3 Phases C thru E. The pilot then falls under parachute at a rate of up to 25 feet per second. Finally, the pilot may absorb up to 2,938 lbs-ft of energy at ground impact.

Overall, ejection is a violent and dynamic event, which happens extremely quickly once the ejection handles are pulled. If the pilot is not in proper ejection position and does not follow proper procedures, serious injuries or death can occur.

Our evaluation focused on the initial phases of the ejection, which include the upward forces on the pilot and the intial windblasts experienced by the pilot while leaving the aircraft and entering the wind stream. The initial phases of ejection are where HMDs and/or NVGs are most likely to be the contributing factor to pilot safety and are the focus of the NDAA request due to the aerodynamic forces at high speeds. We did not evaluate at the parachute deployment or parachute landing fall phases of the ejection because these areas are outside the NDAA request.

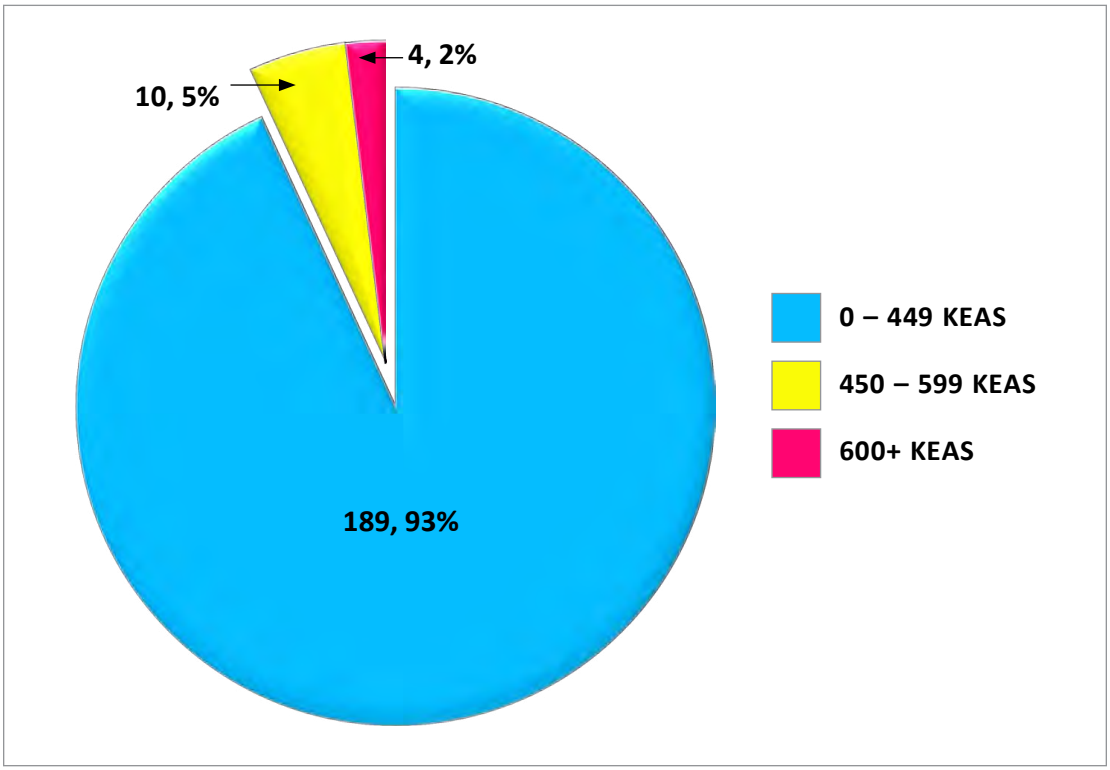
Ejection Data Evaluation Summary

The Air Force and Navy provided flight hours and ejection data that contained aircraft type, model, speed that the ejection occurred, and the type of injury sustained. We limited the data from the Air Force and Navy to only ejection seat equipped aircraft that fly with HMDs and/or NVGs. We further limited it to the Air Force ACES II and Navy NACES seats due to their prevalence and them being the only seats used with HMDs and/or NVGs. We did not evaluate the F-35 ejection seat because it is currently still in development, the aircraft has not finished testing, and there is limited ejection data. We bound the ejection data and flight hours to FY 1995-2014. We selected FY 1995 as the bounding condition because night vision goggles were first introduced to the fleet that year.

Air Force Ejection Data

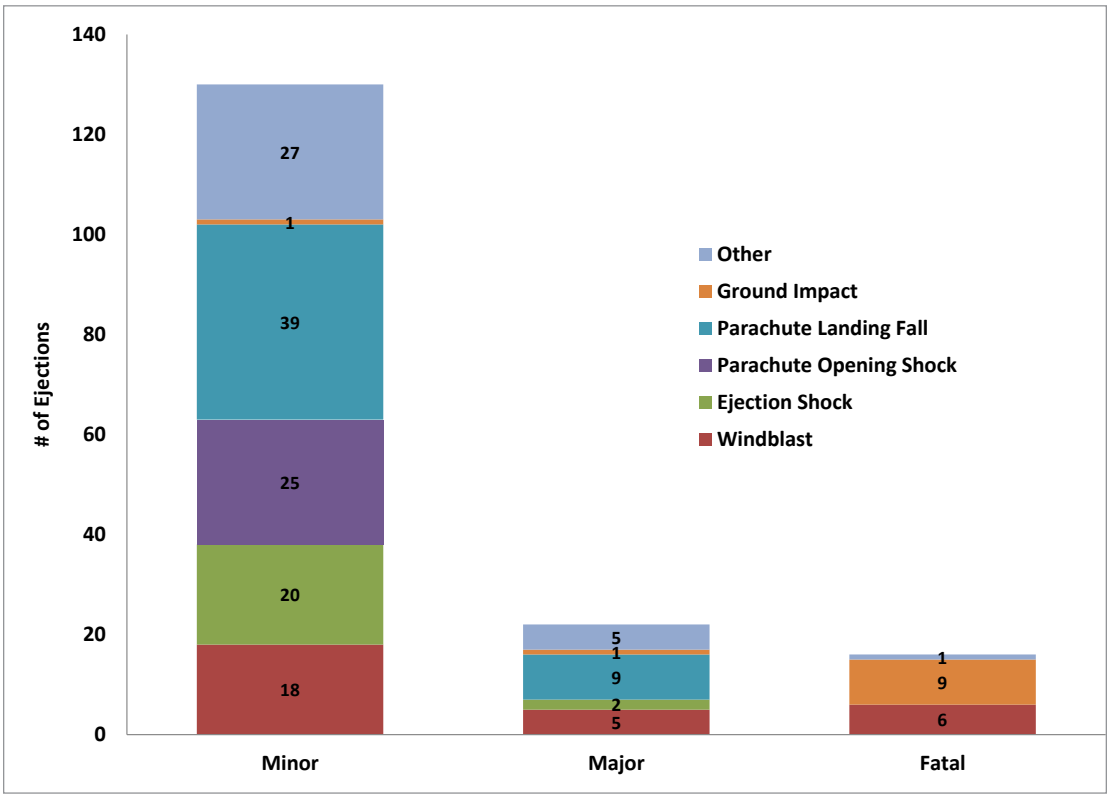
The Air Force provided the OIG ejection data for FYs 1995 to 2014, which covered 203 ACES II ejections on HMDs and/or NVGs-compatible aircraft. Of the 203 ejections, 189 (93-percent) occurred within the safe ejection envelope of 0 to 450 KEAS. Fourteen (7-percent) of those ejections occurred outside the envelope, above 450 KEAS (Figure 4).

Figure 4. Air Force Ejection Speed Breakdown on HMD-Compatible Aircraft



Of 189 ejections occurring below 450 KEAS, 24 (12-percent) resulted in a major or fatal injury. A major injury is considered broken limbs, except fingers and toes, internal injuries, and severe burns. There were 24 major and fatal injuries that occurred below 450 KEAS: 4 due to windblast, 1 due to ejection shock, 9 due to parachute landing fall, 6 due to ground impact (impacting the ground or other object during the ejection phase), and 4 being caused by items such as burns and hypothermia. All of the ejections that occurred above 450 KEAS since 1995 resulted in a major or fatal injury. Data show several injuries are occurring during the parachute-landing phase and not during the initial ejection or windblast phase of the ejection (Figure 5).

Figure 5. Cause of Injury for all Ejections



Head and spinal injuries accounted for 8 (4-percent) of the injuries within the 0 to 450 KEAS design envelope. Across the complete ejection data set, which contains ejections occurring at 0 to 750 KEAS, 13 (6-percent) of the major or fatal injuries were spinal or head injuries with most occurring at higher speeds outside the seat performance envelope.

Further analysis showed that 25 out of 203 total ejections involved HMDs and/or NVGs (Figure 6). Of those 25 ejections, 6 ejections were fatal and 2 resulted in major injuries. The fatal injuries were broken down as follows: three due to ground impact, two due to windblast, and one due to drowning. Also of the 6 fatal ejections with HMDs and/or NVGs, 4 were outside the 0 to 450 KEAS safe ejection envelope. The two major injuries were due to windblast and ejection forces, of which one was outside the safe ejection envelope. The remaining 17 ejections resulted in minor or no injuries.

Figure 6. Ejections with Helmet-Mounted Devices

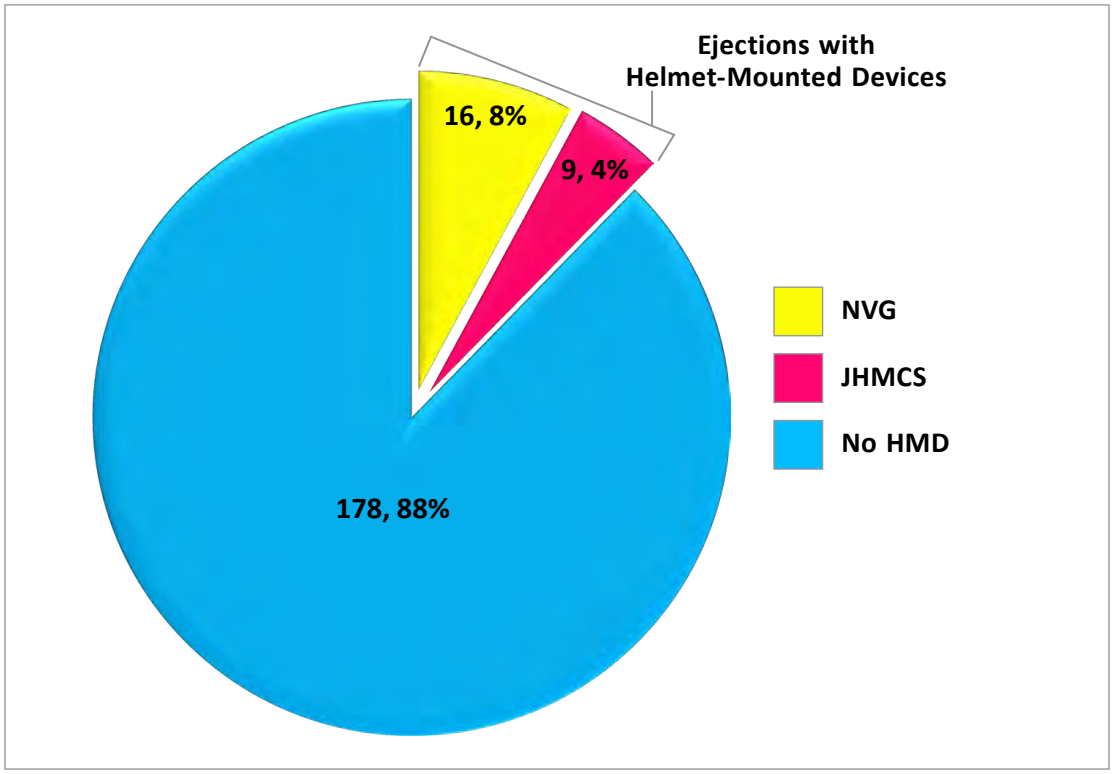
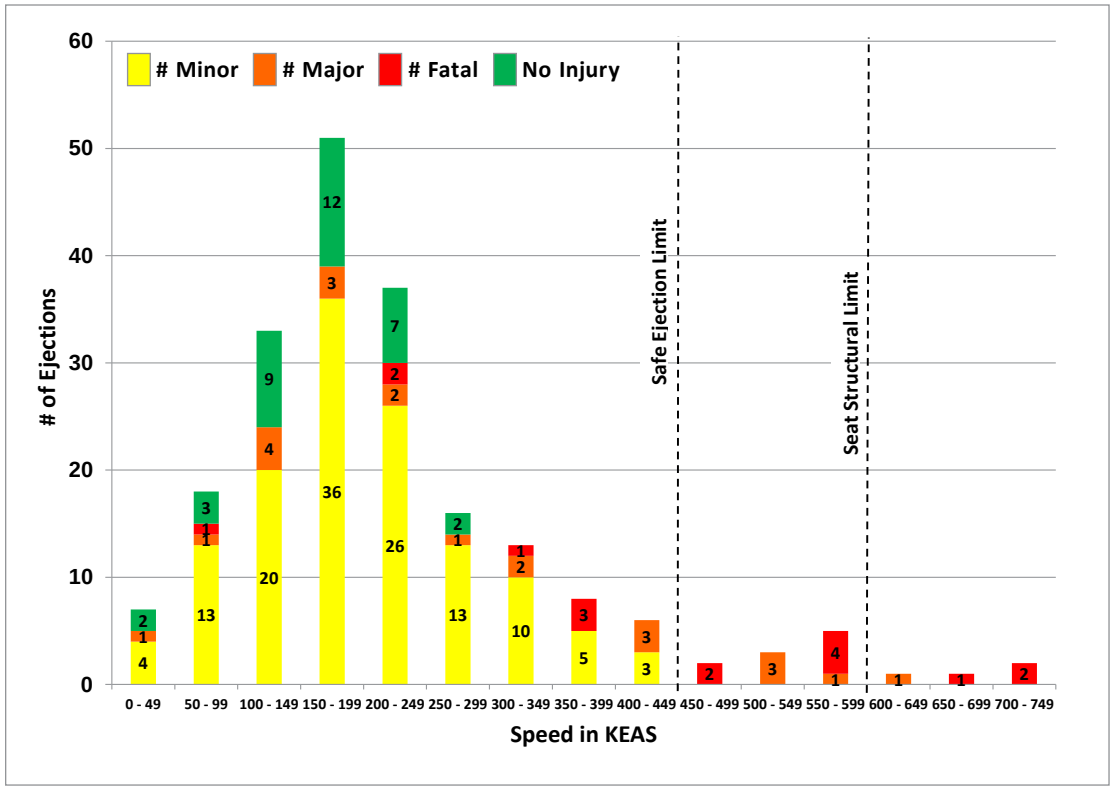


Figure 7. Air Force Ejection Injury Level by Speed

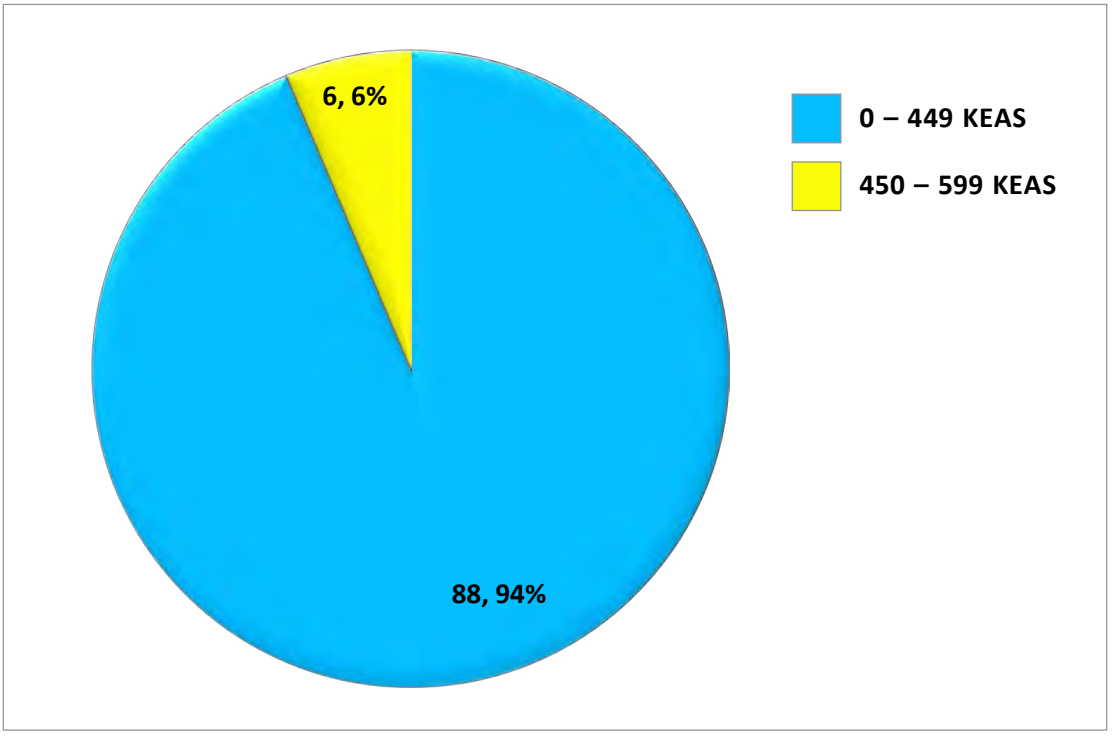


Based on the ejection data, most Air Force aircraft ejections occur within the prescribed seat envelope and result in minor injuries (Figure 7). The data support the flight manual, which indicates that there is higher probability of major or fatal injury above 450 KEAS.

Navy Ejection Data

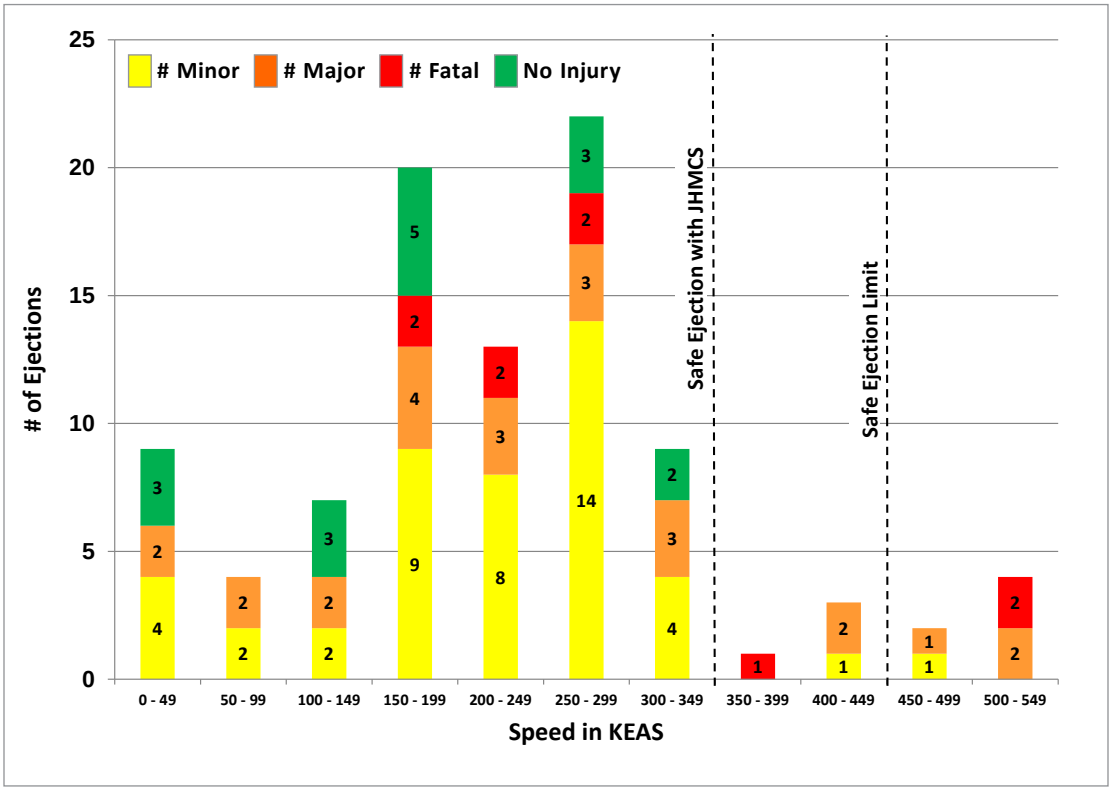
The Navy provided ejection data from FY 1995 through FY 2014 for all aircraft variants. This data was then reduced to only ejection data for HMDs and/or NVGs capable aircraft that contained speed data, which resulted in 94 data points. Upon analysis of the 94 ejections, we found that 88 (94-percent) occurred within the safe ejection envelop of 0 to 450 KEAS and 6 (6-percent) of the ejections occurred outside the envelope (Figure 8).

Figure 8. Navy Ejection Speed Breakdown



The data shows that 28 (32-percent) of the ejections that occurred below 450 KEAS resulted in a major or fatal injury. For the ejections that occurred above 450 KEAS, 5 resulted in a major or fatal injury (Figure 9). The data support the NATOPS, which indicates that there is higher probability of major or fatal injury above 450 KEAS.

Figure 9. Navy Ejection Injury Level by Speed



The ejection data did not always include the overall cause of the injuries and types of injuries sustained by the aircrew. Furthermore, due to the lack of detail in the Navy's data, we could not determine if the aircrew were wearing NVGs and/or HMDs at the time of ejection; thus we could not conclude that it contributed to the injury. We did not evaluate why the Navy's data lacked detail, as it was outside the scope of this evaluation.

Safety Risk Analysis Evaluation Summary

We evaluated the Navy and Air Force's safety risk assessments, which are part of the airworthiness assessment process. Both the Navy and Air Force conducted safety risk assessments for the JHMCS and accepted the additional risk to its aircrew. The joint Air Force and Navy program team conducted multiple system-level tests for their respective aircraft at various airspeeds and with manikins of different sizes and weights to understand the impact of JHMCS to an

ejection event. The program found that the JHMCS display unit remained intact and met requirements to 450 KEAS; however, the JHMCS display unit was stripped from the helmet at 600 KEAS, leaving the pilot with a visor-less HGU-55/P helmet. They further noted that the integrated chin/nape strap (ICNS) that functions to stabilize and hold the JHMCS and helmet on the aircrew may induce higher neck tension loads primarily during high-speed ejections, above 450 KEAS. Consequently, the JHMCS was qualified to 450 KEAS for module retention and facial protection based on that being the qualification speed for the HGU-55/P helmet and the flight manual recommended top speed for safe ejection.

The Air Force stated in its safe-to-fly recommendation that there is no indication that the JHMCS adds significant risk over the current HGU-55/P helmet with ICNS. The Air Force recommended that the JHMCS be employed without operational flight restrictions; however, the Air Force recommended that aircrew flying with it perform neck exercises to strengthen neck muscles. The Navy stated in its risk acceptance letter that JHMCS placed additional weight and aerodynamic drag and lift on the aircrew helmet, causing additional forces to act on the aircrew during ejection. The Navy determined JHMCS represented a serious risk (1D according to MIL-STD-882E). The Navy determined that low-weight pilots have a higher probability of injury and thus have limited their use within the NATOPS. The Navy approved the JHMCS for the F/A-18 for all aircrew except for low-weight pilots, weighing less than 136 lbs., due to the increased risk of injury. Both Services accepted the risks and they mitigate risks to the aircrew through restriction and procedures identified in the flight manuals. However, neither Service conducted risk assessments on NVGs because, according to procedure, they are to be stowed before ejection. Regardless of the helmet system being worn, if aircrew do not properly wear the helmet at all times and follow proper ejection procedure, they are susceptible to head and neck injuries in the event of an ejection.

Furthermore, we analyzed the ejection data obtained from the Navy and Air Force Safety Centers to determine the actual rate of ejection and probability of injury. Based on our analysis of the ejection data combined with the number of flight hours, we determined that the rate of ejection is 1.99E-5 per flight hour for the Navy F-18 and 1.68E-5 per flight hour for Air Force ACES II-equipped aircraft, respectively. The Navy F-18 flies an average of 258,134 hours per year and the

Air Force ACES II-equipped aircraft fly an average 634,988 hours per year. We calculated the rate of major and fatal injury for the Navy is 5.72E-6 and 2.96E-6 per flight hour, respectively. The rate of major and fatal injury for the Air Force is 1.82E-6 and 1.36E-6 per flight hour, respectively (Table 3).

Table 3. Ejection Rates

Service	Average Flight Hours	Rate of Ejection per Flight Hour	Rate of Minor Injury per Flight Hour	Rate of Major Injury per Flight Hour	Rate of Fatal Injury per Flight Hour	Rate of No Injury per Flight Hour
Navy (F-18)	258,134	1.99E-05	6.32E-06	5.72E-06	2.96E-06	4.93E-06
Air Force (HMD Capable Aircraft)	634,988	1.68E-05	1.08E-05	1.82E-06	1.33E-06	2.90E-06

Using MIL-STD-882E, which defines the safety risk acceptance process and assuming that a major or fatal injury would be designated as a catastrophic consequence, the probability of occurrence would be identified as a 1D (catastrophic/remote). This level of risk is usually accepted by the program management office; in this case the aircraft Program Executive Offices.

Finding A

Ejection Seats With Aircrew Wearing HMDs and/or NVGs Meet Criteria

DoD ejection seat equipped aircraft with aircrew wearing NVGs and/or HMDs meet airworthiness criteria in accordance with MIL-HDBK-516B and have been certified safe-to-fly by the appropriate Navy and Air Force safety acceptance authorities. However, both Services noted that there is an increased risk of neck injury during high-speed ejections with HMDs and/or NVGs above 450 KEAS, and an increased potential of neck injuries for low-weight pilots. To mitigate these risks, the Services placed warnings, notes, cautions, and restrictions in the flight manuals.

Discussion

Our analysis of the ejection seat documentation, ejection data, and safety risk analyses for the NVGs and HMDs showed that the seats meet MIL-HDBK-516B airworthiness criteria. The ejection seats were deemed airworthy and provide safe ejections between 0-450 KEAS for aircrew weighing between 136–213 lbs. for the Navy NACES seat and aircrew weighing between 140–211 lbs. for the Air Force ACES II seats. The flight manuals for ejection seat equipped aircraft state that ejections outside these limits pose a greater risk of injury and identify the specific procedures to follow to ensure safe ejection. Both the Navy and Air Force have conducted safety risk assessments and certified the ejection seats with HMDs and NVGs as airworthy. However, both Services have placed warning, notes, cautions, and restrictions in their flight manuals in regards to ejecting with specific HMDs and directing the removal of the NVGs to mitigate potential risks to the aircrew.

The Navy and Air Force noted during their risk assessments that there is an increased risk of injury with the JHMCS above 450 KEAS and for low-weight pilots wearing JHMCS. The Navy cites in their NATOPS that the addition of the JHMCS reduces the safe ejection speed to 350 KEAS and restricts pilots under 136 lbs. from flying with the JHMCS to maintain safe ejection conditions. The Air Force flight manuals inform pilots that the JHMCS failed above 450 KEAS thus the safe ejection speeds are lower for aircrew not within the proper weight limits. Furthermore, our analysis of the Navy and Air Force ejection data showed that most ejections were occurring below 350 KEAS. Additionally, the rate of ejection for the Navy F-18 and Air Forces ACES II seat are 1.99E-5 per flight hour and 1.68E-5 per flight hour, respectively, which makes ejection a remote possibility. Furthermore, the average probability of major or fatal injury is 2.95E-6, which is an order of magnitude smaller.

We believe, based on our evaluation of the safety and ejection data and our calculations of rate of ejection and probability of major or fatal injury, that the ejection seats with HMDs and/or NVGs meet MIL-HDBK-516B criteria. Additionally, if the aircrew is within the prescribed safe ejection operational limits, the addition of HMDs and/or NVGs does not significantly increase the risk of major injury. Finally, we determined that regardless of the helmet system being worn, if aircrews do not properly wear the helmet at all times and follow proper ejection procedures; they are susceptible to an increased risk of head and neck injuries in the event of an ejection.

Management Comments on the Finding and Our Response

Summaries of management comments on the finding and our response are in Appendix B.

Recommendations, Management Comments, and Our Response

Revised Recommendation

As a result of management comments, we revised Recommendation A.3 to allow for the Services to determine the best place for increased emphasis and awareness on proper ejection procedure.

Recommendation A

Although the ejection systems with HMDs and/or NVGs have been deemed airworthy by their respective Services, we recommend that the Navy and Air Force:

1) **Continue to evaluate technology that would improve the overall safety of the pilot during ejections.**
2) **Ensure consistent documentation of aircraft ejection data to increase the data available for ejections with HMD and/or NVGs thus improving the safety risk analysis. The data should include aircraft speed at time of ejection, whether aircrew was wearing HMD and/or NVGs, and type of injury sustained.**
3) **Ensure increased emphasis during training, annual checkrides, and continually stress awareness that aircrew follow proper ejection procedures as identified in NATOPS and the Air Force flight manuals.**

Deputy Assistant Secretary of the Navy, Air Programs Comments

The Deputy Assistant Secretary of the Navy, Air Programs, agreed with the three recommendations, but did not provide details on how the Navy will implement the recommendations. The Deputy indicated that investments in developing advanced escape systems and head-mounted display technologies as integrated systems could expand the safe ejection envelope to the aircraft's full certified airspeed and enable the Services to modify and/or remove the existing warnings, notes, cautions, and restrictions. The Deputy also noted that other Navy activities may be responsible for implementing the recommendations.

Our Response

Comments from the Deputy Assistant Secretary of the Navy, Air Programs, do not address all the specifics of the recommendations. Therefore, we request further comments in response to the final report. For each recommendation, we ask that the comments:

- state what technology or actions are being pursued to improve the overall safety of the pilots during ejection,
- provide a plan for how ejection data will be collected,
- explain how training will be improved, and
- estimated implementation dates.

Air Force Life Cycle Management Center, Human Systems Division, Comments

The Air Force Life Cycle Management Center, Human Systems Division, agreed with the three recommendations and will implement them as follows.

1) The Air Force is implementing the ACES II Safety and Sustainability Improvement Program (SSIP), which will address both sustainment and safety improvements for ACES II seats. SSIP will focus on improved recovery parachutes to minimize parachute landing fall injuries, faster deploying drogue parachutes for increased stability, passive head and neck protection, and limb restraints.

2) The Air Force already captures ejection data to include airspeed, whether the aircrew was wearing HMDs and/or NVGs, and injuries sustained within the Air Force Safety Automated System, which is the database of record for safety investigations. Although the Air Force does not specifically require the recording of other HMDs being worn, this information is normally captured and reported during the investigations. However, the comments noted that additional improvements to the Air Force Safety Automated System will be pursued to capture the use of other HMDs.

3) The Human Systems Division through the Air Force Life Cycle Management Center, aircraft program offices, and Air Education and Training Command and using commands can communicate the need for increased emphasis on proper ejection procedure. However, the proper emphasis and training methodology is ultimately up to Air Education and Training Command and using commands for implementation.

Our Response

Comments from the Air Force Life Cycle Management Center, Human System Division, address all specifics of the recommendations, and no further comments are required.

Finding B

JSSG Handbook Needs to be Updated

We determined the JSSG, "Crew Systems, Emergency Egress Handbook," dated October 1998 has not been revised or updated as required by DoD 4120.24-M, "Defense Standardization Program (DSP), Policies and Procedures." The Handbook should be reviewed and validated every 5 years. Not updating the Handbook can result in the specifications becoming out dated and not taking into account advancements in technology, changes in the industry, or new policy.

Discussion

The JSSG-2010-11 had not been validated in accordance with DoD 4120.24-M, "Defense Standardization Program (DSP), Policies and Procedures." DoD 4120.24-M requires standards and handbooks to be reviewed every 5 years to verify that they are valid and do not require revision or cancelation. The JSSG-2010-11 had not been reviewed since October 1998 when the document was originally issued. Additionally, a review of the document showed that it does not address helmet-mounted devices and the expanded pilot population to accommodate the wider range of operational weights.

Recommendation, Management Comments, and Our Response

Recommendation B

We recommend that the Navy and Air Force review and update the JSSG to reflect changes in policy and technology that have occurred in the last 16 years.

Deputy Assistant Secretary of the Navy, Air Programs, Comments

The Deputy Assistant Secretary of the Navy, Air Programs, partially agreed with the recommendation. The Deputy acknowledged that there is a need to update the JSSG, "Crew Systems Emergency Egress Handbook;" however, he stated that the current document does not directly result in outdated specifications nor does it fail to take advantage of advanced technologies. The Deputy also stated that the document provides guidance when developing system requirements and that opportunity exists to apply state-of-the-art technology and current policy via the system specification. In addition, the Deputy pointed out that an update would require coordination across the Services.

Our Response

We agree that the document does not preclude the program from applying state-of-the-art technology within the system specification. However, we request that the Deputy Assistant Secretary of the Navy, Air Programs, coordinate with the Air Force during the review and revision of JSSG-2010-11.

Air Force Life Cycle Management Center, Human Systems Division, Comments

The Air Force Life Cycle Management Center, Human Systems Division, agreed and will begin compiling updated injury criteria for an Air Force Airworthiness Bulletin to serve as interim guidance until the JSSG-2010-11 can be updated. The comments also stated that a complete review and revision of JSSG-2010-11 will be coordinated with the Navy by June 2016.

Our Response

Comments from the Air Force Life Cycle Management Center, Human Systems Division, address the specifics of the recommendation, and the actions meet the intent of the recommendation. We request that the Air Force Life Cycle Management Center, Human Systems Division, provide the DoD OIG with a copy of the Air Force Airworthiness Bulletin when it is completed in June 2015 and a copy of the updated JSSG-2010-11 when it completed in June 2016.

Appendix A

Scope and Methodology

We conducted this evaluation from August 21, 2014, through January 12, 2015, in accordance with the Council of Inspectors General on Integrity and Efficiency Quality Standards for Inspection and Evaluation. Those standards require that we plan and perform the evaluation to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our evaluation objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our evaluation objectives.

This evaluation was limited to only ejection seat equipped aircraft that fly with NVGs and/or HMDs. We limited this evaluation to the Air Force ACES II and Navy NACES seats due to their prevalence and them being the only seats used with HMDs and/or NVGs. We did not evaluate the F-35 ejection seat because the F-35 is still in development, the aircraft has not finished qualification testing, and there is limited ejection data.

The DoD IG first met with the Air Force Materiel Command, Life Cycle Management Center, and its Human Systems Division to get an overview of ejection history, ejection forces, and determine which aircraft use ejection seats and HMDs and/or NVGs. We then evaluated the risk assessment for each NVG and/or HMD and evaluated ejection data provided by the Air Force Safety Center to determine if the configurations met airworthiness criteria. Subsequently, we met with the Naval Air Systems Command, Air Crew Systems, and repeated the process.

We analyzed ejection data and flight hours from FY 1995 to 2014. We selected FY 1995 as the bounding condition because it is the year night vision goggles were introduced to the air fleet. During the analysis of the ejection data, we disregarded aircraft that do not support NVGs and/or HMDs and prepared a controlled/limited dataset. The data were then categorized (or organized) by aircraft type, ejection speed, and injury level. From that limited dataset, we determined which ejections occurred within the envelope. The overall ejection rate and probability of serious or fatal injury were calculated to determine if it met the airworthiness criteria.

We also reviewed the safety risk assessments conducted by each Service for each HMDs and/or NVGs. We specifically evaluated how the safety risks were calculated. We reviewed safety risk assessment for the JHMCS and HMIT system. However, no safety risk assessment was done by either Service for NVGs.

Appendix B

Management Comments on Finding A and Our Response

Deputy Assistant Secretary of the Navy, Air Programs Comments

The Deputy Assistant Secretary of the Navy, Air Programs, cited that the report was socialized within Naval Air Systems Command/Air Crew Systems, NAVAIRSYSCOM, and stakeholders including the Assistant Secretary of the Navy (Research, Development, and Acquisition) and the Chief of Naval Operations staff. However, the responsibility of implementing the recommendations does not fall solely on NAVAIRSYSCOM; other Navy activities may be responsible for implementation.

Our Response

We agree that NAVAIRSYSCOM is not solely responsible for implementing the recommendations. However, we do request that NAVAIRSYSCOM provide support to the Navy activities implementing the recommendations contained within this report.

Air Force Life Cycle Management Center, Human Systems Division, Comments

The Air Force Life Cycle Management Center, Human Systems Division, generally agreed with Finding A. The comments noted that when the ACES II seat was originally developed, it was not accepted through the current airworthiness process, however it was later reviewed using the current process and deemed airworthy in accordance with MIL-HDBK-516B criteria. The comments from Air Force Life Cycle Management Center, Human Systems Division, further stated the report answers the question posed by Congress; however, it does not fully address the complexity of the issues presented by the combination of ejection seats, HMDs, pilot weight, and ejection speed. The report does not quantify the increased risk of low-weight pilots wearing HMDs and/or NVGs. In addition, the comments stated that the risk of lightweight pilots sustaining a major injury could be as high as 40 percent, which is stated in the, "Report on Health and Safety Risks Associated with Ejection Seats," May 2014, that it provided to Congress. However, there have not been any low-weight pilot ejections since 1995 with or without HMD and/or NVGs; thus, there is no operational data to validate the prediction.

Our Response

The DoD OIG acknowledges that the ACES II seats were originally accepted under a legacy process through an Executive Engineering Independent Review Team, which reviewed the aircraft program prior to first flight and after successful completion of the test program to show the platform was airworthy. We also acknowledge that the legacy platforms were then reviewed through the current airworthiness process to show they meet MIL-HDBK-516B criteria. We reviewed the, "Report on Health and Safety Risks Associated with Ejection Seats," May 2014 during the evaluation; however, the 43-precent of major injury for low-weight pilots would be at aircraft velocities close to 600 KEAS. Furthermore, the cited report does not quantify the risk in accordance with MIL-STD-882E principles and only provides a piece of the overall risk analysis for low-weight pilots. The actual ejection data show that, in general, ejections are occurring below 450 KEAS with very few occurring at 600 KEAS. Additionally, the Air Force Flight Manuals and this report document that there is an increased chance of major injury for low-weight pilots or pilots within the acceptable seat weight limits if the ejections occurs over 450 KEAS. Thus, there was no change to Finding A.

Management Comments

Deputy Assistant Secretary of the Navy, Air Programs

DEPARTMENT OF THE NAVY
OFFICE OF THE ASSISTANT SECRETARY
RESEARCH, DEVELOPMENT AND ACQUISITION
1000 NAVY PENTAGON
WASHINGTON DC 20350-1000

FEB 2 2015

MEMORANDUM FOR INSPECTOR GENERAL, DEPARTMENT OF DEFENSE

SUBJECT: Navy Response to DoDIG Draft Audit Report on "Evaluation of Aircraft Ejection Seat Safety when using Advanced Helmet Sensors", D2014-DT0TAD-0002.000, Dated 12 January 2015

The Navy has reviewed the subject report and concurs with the findings and recommendations. PMA-202 and all NAVAIRSYSCOM stakeholding Competencies assisted the DoDIG during the conduct of this audit, and the report and responses were socialized within the offices of the Assistant Secretary of the Navy (Research, Development and Acquisition) and the Chief of Naval Operations. Our response to your draft report is enclosed.

Note that responsibility for implementing recommendations does not fall solely on NAVAIRSYSCOM or PMA-202. Other Navy activities, such as the Chief of Naval Operations, Chief of Naval Air Forces, Chief of Naval Air Training, and the Navy Safety Center, among others, may be responsible for implementation. If you have any questions, please contact Mr. James Ruocco at (703) 695-4949 or jim.ruocco@navy.mil.

Gary K. Kessler
Deputy Assistant Secretary of the Navy,
Air Programs

Attachments:
As stated

Deputy Assistant Secretary of the Navy, Air Programs (cont'd)

NAVY RESPONSE TO
DODIG DRAFT AUDIT REPORT ON "EVALUATION OF AIRCRAFT EJECTION SEAT SAFETY WHEN USING ADVANCED HELMET SENSORS",
D2014-DT0TAD-0002.000, DATED 12 JANUARY 2015

Finding A: Ejection Seat with Aircrew Wearing HMDs and/or NVGs Meet Criteria

DoD ejection seat equipped aircraft with aircrew wearing NVGs and/or HMDs meet airworthiness criteria within MIL-HDBK-516B and have been certified safe-to-fly by the appropriate Navy and Air Force safety acceptance authorities. However, both Services noted that there is an increased risk of neck injury during high-speed ejections with HMDs and/or NVGs above 450 Knots Equivalent Air Speed (KEAS), and increased potential of neck injuries for low-weight pilots. To mitigate these risks, the Services placed warnings, notes, cautions, and restrictions in the flight manuals.

Response: Concur.

Recommendation A.1: Although the ejection systems with HMDs and/or NVGs have been deemed airworthy by their respective services, we recommend that the Navy and Air Force continue to evaluate technology that would improve the overall safety of the pilot during ejections.

Response: Concur. Investment in development of advanced escape systems and head mounted display technologies as integrated systems could expand the safe ejection envelope to the aircraft's full certified airspeed and enable the Services to modify and/or remove the existing necessary warnings, notes, cautions and restrictions.

Recommendation A.2: Although the ejection systems with HMDs and/or NVGs have been deemed airworthy by their respective services, we recommend that the Navy and Air Force ensure consistent documentation of aircraft ejection data to increase the data available for ejections with HMD and/or NVGs thus improving the safety risk analysis. The data should include aircraft speed at time of ejection, whether aircrew was wearing HMD and/or NVGs, and type of injury sustained.

Response: Concur

Recommendation A.3: Although the ejection systems with HMDs and/or NVGs have been deemed airworthy by their respective services, we recommend that the Navy and Air Force ensure through annual checkrides, increased emphasis during training, and continually stressed awareness, that aircrew are following proper ejection procedures as identified in NATOPS and the Air Force flight manuals.

Response: Concur

Finding B: JSSG Handbook Needs to be Updated

We determined the JSSG, "Crew Systems, Emergency Egress Handbook," dated October 1998 has not been revised or updated as required by DoD 4120.24-M, "Defense Standardization

Enclosure (1)

Deputy Assistant Secretary of the Navy, Air Programs (cont'd)

NAVY RESPONSE TO
DODIG DRAFT AUDIT REPORT ON "EVALUATION OF AIRCRAFT EJECTION SEAT SAFETY WHEN USING ADVANCED HELMET SENSORS",
D2014-DT0TAD-0002.000, DATED 12 JANUARY 2015

Program (DSP), Policies and Procedures." The handbook should be reviewed and validated every 5 years. Not updating the Handbook can result in the specifications becoming out dated and not taking into account advancements in technology, changes in industry, or new policy.

Recommendation B.1: Recommend that the Navy and Air Force review and update the JSSG to reflect changes in policy and technology that have occurred in the last 16 years.

Response: Partially **concur.** We acknowledge the current status of the JSSG Crew Systems, Emergency Egress Handbook, and endorse the need for update, however the current content does not directly result in outdated specifications nor fail to take advantage of advanced technologies. The JSSG is a document that provides guidance when developing system requirements and specifications and is not intended to constitute the formal performance requirements levied on the system under development. Opportunity exists to apply state of the art technology and current policy via performance requirements within the system specifications to ensure the system can benefit from those technologies. As a Joint Service Document, updates require a coordinated investment across both services to involve the appropriate technical authorities.

General Comments: The Navy concurs with the findings and recommendations. PMA-202 and all NAVAIRSYSCOM stakeholding Competencies assisted the DoDIG during the conduct of this audit, and the report and responses were socialized with the Assistant Secretary of the Navy (Research, Development and Acquisition) and the Chief of Naval Operations staffs. Responsibility for implementing recommendations does not fall solely on NAVAIRSYSCOM. Other Navy activities such as the Chief of Naval Operations (NATOPS/ Safety/Training), Chief of Naval Air Forces (NATOPS/Safety/Training), Chief of Naval Air Training and the Navy Safety Center, among others, may be responsible for implementation.

Classification Review: Document appropriately marked.

Enclosure (1)

Air Force Life Cycle Management Center, Human Systems Division

DEPARTMENT OF THE AIR FORCE
AIR FORCE LIFE CYCLE MANAGEMENT CENTER
WRIGHT-PATTERSON AIR FORCE BASE OHIO

MEMORANDUM FOR INPSECTOR GENERAL
DEPARTMENT OF DEFENSE

FROM: Human Systems Division (AFLCMC/WNU)
1981 Monahan Way, Building 12, Area B
Wright-Patterson AFB, OH 45433-7217

SUBJECT: Comments to Draft Report, Evaluation of Aircraft Ejection Seat Safety When Using Advanced Helmet Sensors (Project Number: D2014-DTOTAD-0002.000)

1. Our team has reviewed the subject report and provides the following comments regarding the findings and recommendations:

a. **Finding A**: Concur with comment. Legacy ejection seats systems such as the Advanced Concept Ejection Seat (ACES) II, were not originally accepted in to service by the current Airworthiness process since they were fielded prior to the establishment of the Airworthiness process. The Military Type Certification is issued based upon acceptance of legacy airworthiness processes, as documented in accordance with the legacy certification checklist that defined the limitations, restrictions, authorized configuration, and approved operational and maintenance technical orders. While the finding and discussion answer the question asked by Congress they fail to address the complexity of the issues presented by the combination of ejection seats, Helmet Mounted Displays (HMDs), pilot weight and ejection speed. While the report mentions that there is an increased injury risk predicted for light weight pilots ejecting with HMDs or Night Vision Goggles (NVGs) it fails to quantify that increased risk. As reported to Congress in "Report on Health and Safety Risks Associated with Ejection Seats", May 2014 the risk for light weight pilots could be as high as a 40% chance of a major injury. Unfortunately since there have not been any lightweight ejections (below 140 lbs) since 1995, with or without an HMD or NVG, there is no operational data to validate this prediction.

(1) **Recommendation A1**: Human Systems Division (HSD), AFLCMC/WNUV, is initiating the ACES II Safety and Sustainability Improvement Program (SSIP), which includes both sustainment and safety improvements for ACES II seats. Safety upgrades being targeted for the seats include improved recovery parachutes to minimize parachute landing fall injuries, faster deploying drogue parachutes for increased stability, passive head and neck protection and limb restraints where warranted. The ACES II SSIP for the Global Strike Command (GSC) B-2 aircraft has a vetted requirement and initial Congressional appropriations have been provided to support this effort. In addition requirements and funding for ACES II seat upgrades in Air Combat Command aircraft are also being worked.

(2) **Recommendation A2**: The Air Force Safety Automated System (AFSAS), which is the database of record for safety investigations, already captures ejection related data including airspeed, whether or not aircrew were wearing NVGs, and injuries sustained. While not specifically requiring the

Air Force Life Cycle Management Center, Human Systems Division (cont'd)

Final Report Reference

recording of other HMDs being worn, this information is normally captured and reported during the investigation. Additional improvements to the AFSAS database will be pursued to capture the use of other HMDs.

(3) **Recommendation A3**: This should be reworded as "Ensure increase emphasis during training and continually stress awareness that aircrew follow proper ejection procedures as identified in NATOPS and the Air Force flight manuals." Rationale: As currently worded, the recommendation requires doing this "through annual check rides." Annual check rides represent a small portion of the overall training and evaluation that an aviator goes through. There are other opportunities for this increased emphasis and awareness, such as during academics, ground based/simulator training, flight briefings, etc., that may be more appropriate and effective at accomplishing the intent of the recommendation. The reworded recommendation above leaves it open for the services to determine the best place for this increased emphasis and awareness, so that the most effective means can be determined and implemented. **Note**: HSD can communicate the need for increased emphasis for following proper procedures through the Air Force Life Cycle Management Center aircraft program offices, Air Education and Training Command (AETC) and using commands but the proper emphasis and training methodology is ultimately up to AETC and the using commands for implementation.

Revised Recommendation A.3

b. **Finding B**: Concur

(1) **Recommendation B**: As an initial step, Engineering Directorate, AFLCMC/EZ-EN, has begun compiling updated injury criteria for a USAF Airworthiness Bulletin as interim guidance until JSSG-2010-11 can be fully updated (Expected Completion Date (ECD): June 2015).

(2) In addition, a complete review and revision will be initiated and coordinated with the United States Navy (ECD): June 2016).

2. Additional consolidated team comments regarding the report are included in the attachment.

3. Please address any questions to Mr. James M. Barnaba, Chief Engineer, AFLCMC/WNU, at DSN: 798-3024, Commercial: (937) 938-3024, or Email Address: James.Barnaba@us.af.mil.

WILLIAM A. MCGUFFEY, Col, USAF
Chief, Human Systems Division
AFPEO Agile combat Support

Attachment:
Additional Comments

Air Force Life Cycle Management Center, Human Systems Division (cont'd)

Final Report Reference

HUMAN SYSTEMS DIVISION (AFLCMC/WNU)

Additional Team Comments on Evaluation of Aircraft Ejection Seat Safety When Using Advanced Helmet Sensors (Project Number: D2014-DTOTAD-002.000)

Page 3, Air Force, Paragraph 2: "...the item should not cause any new hazards to the user..." suggest "...the item should not cause unacceptable hazards to the user...". Our processes and those of MIL-STD-882 consistently allow our Program Managers or PEOs to accept risks (hazards). **Revised**

Page 3, Air Force, Paragraph 2: The Airworthiness discussion in the last two sentences is a little backward. The aircraft program office declares whether or not the aircrew equipment (the HMD or NVG in this context) affects the Airworthiness Certification to their aircraft or not. EN-EZ are the ones who granted that airworthiness and will step in to reassess if and when the aircraft program office declares an impact. It is true that EN-EZ provides the guidance to the program offices in making this decision but it is not true that the program office makes the overall airworthiness determination; EN-EZ does. **Revised**

Page 3, Air Force, Paragraph 3: Change "program office" to "program offices". **Revised**

Page 3, Air Force, Paragraph 3: Again, the Program Office does not certify the air vehicle system as airworthy. They make an airworthiness impact or no impact decision relative to the aircrew flight equipment (NVG and/or HMD). EN/EZ is the airworthiness certifier. The TAA grants Airworthiness by issuing the Military Flight Release or the Military Type Certificate not the program offices. **Revised**

Page 4, Navy, Paragraph 2: Change "modified aircrafts" to "modified aircraft".

Page 5, Helmet-Mounted Device, Paragraph 3: Change "...4.81 lbs. for the night version." to "...4.81 lbs. with night vision goggles". "the night version" more accurately refers to the Night Vision Cueing and Display (NVCD) module that the Navy uses and the Air Force rejected in Operational Testing. What is in your picture is not a night vision device with JHMCS symbology (the NVCD), but is a night vision goggle mounted to a JHMCS helmet shell with no display symbology. **Revised**

Page 5, Helmet-Mounted Device, Paragraph 3: Change "3.95 lbs. for the night version without NVGs" to "3.95 lbs. for the night version without NVGs and 5.05 lbs. with NVGs." Makes an apples-to-apples comparison with the other systems. **Revised**

Page 5, Helmet-Mounted Device, Paragraph 3: Change "However, HMDs not easily removed or stowed." to "HMDs are not removed and stowed because they are designed to provide facial protection during ejection. " The JHMCS, HMIT day, and HMIT night visors are designed for and are required for ejection safety. **Revised**

1

Air Force Life Cycle Management Center, Human Systems Division (cont'd)

Final Report Reference

Page 6, Table 1: T.O. 14D-1-1, USAF Aircrew Flight Equipment Clothing and Equipment authorizes AVS-9 for B-52. Although we focused on ACES II platforms because that is where the majority of ejections occur, it is not accurate to say that AN/AVS-9s are not used on the B-52.

Revised

Page 6, Table 1: Change "Northrup" to "Northrop"

Revised

Page 7, NACES: Change"... 0 to 450 KEAS, which includes helmet." to "...0 to 450 KEAS." The words "which includes helmet" are not applicable to this sentence.

Revised

Page 7, ACES 5, line 5: Change "ACE 5" to "ACES 5".

Revised

Page 8, Ejection Sequence, Paragraph 1: Change "...ACES II mode 2 ejection at 600 KEAS..." to "...ACES II mode 2 ejection below approx. 2000 ft. MSL at 600 KEAS..." Above approx. 2000 ft. MSL would be mode 3.

Page 8, Ejection Sequence, Paragraph 1: Suggest changing "...thrust from the seat catapult..." to "thrust from the seat catapult/main rocket burn". Adds to clarity.

Page 8, Ejection Sequence, Paragraph 1: Suggest changing "This upward force causes a downward reaction on the pilot's body and can force the head down." to "The upward thrust or upward acceleration of the ejection seat causes the pilot's body to translate in the opposite direction of the seat. This action causes the pilot's body to push into the ejection seat pan, and typically causes the pilot's head to roll forward into the chest." Adds to clarity.

Page 8, Ejection Sequence, Paragraph 1: Change last sentence to "Per procedure, the pilot is instructed to, but in practice rarely has time to, remove the NVGs prior to ejection; if they do not, the upward ejection force or the windblast has been shown to typically remove the devices However, this does not necessarily mitigate the risk of neck injury since the NVG separation may occur after the neck has already experienced significant multi-axial loading" This wording more accurately reflects reality:

- **16 Ejections with NVGs, of these:**
  - 12 where NVGs not removed prior to ejection (75%)
  - 2 where NVGs were removed (12.5%)
  - 2 where it was unknown (12.5%)

Page 8, Ejection Sequence, Paragraph 2: Change "...chin straps are not tight enough,..." to "...chin straps are not tight enough, or the visor is lost in day or not worn with NVGs,..." Adds more detail to the dynamics.

Page 8, Ejection Sequence, Paragraph 3: Suggest changing "parachute being released" to "parachute being deployed". More appropriate terminology.

Revised

2

Air Force Life Cycle Management Center, Human Systems Division (cont'd)

	Final Report Reference
Page 9, Ejection Sequence, Paragraph 6: Change "...HMDs and/or NVGs would be a contributing factor..." to "...HMDs and/or NVGs are most likely to be a contributing factor...". They do contribute to other phases.	**Revised**
Page 10, Air Force Ejection Data, Paragraph 1: Change "envelop" to "envelope".	**Revised**
Page 10, Air Force Ejection Data, Paragraph 2: Change "All of the ejections that occurred..." to "All of the ejections since 1995 that occurred...". There were ejections prior to 1995 that did not have major or fatal injuries.	**Revised**
Page 12, Figure 7: It is very difficult to distinguish Major (orange) from Fatal (red). For some odd reason, it is much easier to do so in Figure 9.	**Revised**
Page 16, Table 3: Rates are a methodology for determining the level at which a risk decision is made. In order to provide complete decision information, the Air Force requires (per AFI 91-202) that the predicted losses be calculated.	
Page 16, Table 3: Using the numbers from Table 3, assuming the same average flt-hrs/year and same ejection/injury rates, we can predict over the next 10 years: **Navy**: 51 Ejections 16 Minor Injuries 15 Major Injuries 8 Fatal Injuries 13 No Injuries Air Force: 107 Ejections 69 Minor Injuries 12 Major Injuries 8 Fatalities 18 No injuries **Combined Navy+Air Force Fatal**: 16 **Combined Navy+Air Force Major**: 27	
Page 20, Scope and Methodology, Paragraph 3: Change "Human Systems Divisions" to "Human Systems Division".	**Revise, page 23**
Page 20, Scope and Methodology, Paragraph 3 and Paragraph 5: Change "each HMDs and/or NVGs" to "each HMD and/or NVG" or delete the word "each"; either works.	**Revise, page 22**

3

Acronyms and Abbreviations

ACES	Advanced Concept Ejection Seat
AFI	Air Force Instruction
AFLCMC	Air Force Life Cycle Management Center
AFLCMC/EN-EZ	Air Force Life Cycle Management Center, Engineering and Technical Management/Services Directorate
AFPD	Air Force Policy Directive
DSP	Defense Standardization Program
HMD	Helmet-Mounted Display
HMIT	Helmet-Mounted Integrated Targeting
HSD	Human System Division
ICNS	Integrated Chin and Nape Strap
JHMCS	Joint Helmet-Mounted Cueing System
JSSG	Joint Service Specification Guides
KEAS	Knots Equivalent Air Speed
MIL-HDBK	Military Handbook
lbs.	Pounds
NACES	Navy Aircrew Common Ejection Seat
NATOPS	Naval Air Training and Operating Procedures
NAVAIR	Naval Air Systems Command
NDAA	National Defense Authorization Act
NVG	Night Vision Goggles
OIG	Office of Inspector General
PNVG	Panoramic Night Vision Goggles
SSIP	Safety and Sustainability Improvement Program
UTAS	United Technologies Corporation Aerospace Systems
UTC	United Technologies Corporation

Whistleblower Protection
U.S. Department of Defense

The Whistleblower Protection Enhancement Act of 2012 requires the Inspector General to designate a Whistleblower Protection Ombudsman to educate agency employees about prohibitions on retaliation, and rights and remedies against retaliation for protected disclosures. The designated ombudsman is the DoD Hotline Director. For more information on your rights and remedies against retaliation, visit www.dodig.mil/programs/whistleblower.

For more information about DoD IG reports or activities, please contact us:

Congressional Liaison
congressional@dodig.mil; 703.604.8324

Media Contact
public.affairs@dodig.mil; 703.604.8324

Monthly Update
dodigconnect-request@listserve.com

Reports Mailing List
dodig_report@listserve.com

Twitter
twitter.com/DoD_IG

DoD Hotline
dodig.mil/hotline

DEPARTMENT OF DEFENSE | INSPECTOR GENERAL

4800 Mark Center Drive
Alexandria, VA 22350-1500
www.dodig.mil
Defense Hotline 1.800.424.9098